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CONTENTS.

EXPERIMENTS ON THE MANURING OF GREEN CROPS CARRIED OUT ON TEA ESTATES NEAR JORHAT.

In recent numbers of the Quarterly Journals* descriptions have been given of experiments carried out at Borbhetta near the Tocklai Experimental Station to determine the effect of different phosphatic manures on green crops. As the result of these experiments, it was shown that, on Borbhetta soil, phosphatic manures, supplied in liberal quantities, accompanied by a small quantity of lime, not sufficient, however, to neutralise the acidity of the soil, and by sulphate of ammonia and sulphate of potash in quantities which supplied 20 lbs. of nitrogen and 56 lbs. of potash per acre respectively, produced very marked increases in the six weeks' growth of such green crops as cowpeas, etc.

In arranging this year's programme it occurred to us that if similar experiments could be carried out on other soils in the neighbourhood of the Tocklai Experimental Station, but at a distance which would not introduce a new value for the climate factor, our information about the action of phosphatic manures would be much increased, and if it were found that other soils in this neighbourhood responded to phosphatic manures in approximately the same manner, we would have increased confidence in recommending them. That is to say what we chiefly wished to determine was whether the action of the different phosphatic manures used differs by so little that recommendations for treatment of the soil of a large area could be based on these series of experiments.

That, however, very considerable differences are produced by these manures when used on different soils, will be evident from the following description, though the experiments have confirmed what we thought probable, namely, that on all these soils phosphatic manures are of considerable value.

* Indian Tea Association, Scientific Deparlment—Quarterly Journals—Pt. IV of 1915, Pts. III and IV of 1916.

With the co-operation of the managers of three tea estates in the district, we have been able to carry out these experiments. The gardens chosen were Gotoonga and Sangsua of the Moabund Tea Company, and Boisahabi of the Jhanzie Tea Association, Ltd. The soils of these estates differ distinctly from the soil of Borbhetta, and, therefore, we expected that the results of experiments, carried out in the same way in each case, might also differ.

The soil of the experimental plots at Gotoonga is of the lightest sub-type which occurs within the Jorhat district and those of Borbhetta and Sangsua belong to the heaviest sub-type, the Borbhetta soil being the lighter of the two. The actual differences between these three soils are not so great as this description indicates, on account of the soils of these districts being very even in character and the method of classification into sub-types being such as to draw rather fine distinctions between individual soils which really have much in common. All these soils contain about 50% of fine sand with decreasingly smaller quantities of silt, fine silt, and clay, the amount of the coarse sand being very variable. The Boisahabi soil is distinctly heavier, and fine sand no longer preponderates largely though it is still the chief ingredient, for silt and fine silt are present in only slightly less quantity, the amount of clay being considerably less and coarse sand being present only in traces.

The Gotoonga Experiment.

Gotoonga division of the Moabund Tea Company is situated about 12 miles distance from Tocklai on the Kamarbandhali—the Road between Jorhat and Golaghat.

Although Gotoonga Tea Estate is in the Jorhat district, the soil generally shows considerable resemblance to the Golaghat type, which is distinctly redder and more clayey than the soils usually found in the Jorhat district. The soil of the experimental area, however, is distinctly lighter than that of the surrounding land, and is similar to the lightest type of Jorhat district soil. The manager of the estate describes it as "a light sandy loam with a sub-soil of rather stiffer soil, approaching the texture of clay." The following are mechanical analyses of two samples of the surface soil of these plots taken one at each end of the experimental area.

They differ from each other rather more than was expected, but both show the soil to be considerably lighter than that of either of the other experimental areas.

GOTOONGA.

Mechanical Analyses.

Calculated on soil dried at 100°C.

Soluble in diluto acid	1·66	0·39
Coarse Sand	11·23	29·33
Fine Sand	56·92	45·89
Silt	11·10	7·56
Fine Silt	9·91	7·24
Clay	7·19	6·53
Loss on ignition	2·06	2·32
Total ...	100·07	99·26

These soils contain ·058% and ·064% respectively of phosphoric acid, the citric acid soluble phosphoric acid being 009% and ·005%. The citric acid soluble potash is ·009% in both samples.

The land on which this experiment was made was a slightly undulating plateau well raised above rice-field level, with a gradual slope from north to south. It had previously been under tea, which has now been abandoned.

The average yearly rainfall recorded on this estate is about 72 inches. The daily rainfall during the time that the cowpeas were growing was as follows :—

Date.	Inches.	Date.	Inches.	Date.	Inches.
June, 8	·12	June, 21	·84	July, 13	·80
9	1·50	25	·21	14	·08
10	1·54	26	·51	16	1·01
11	·10	29	1·36	17	·07
12	·21	30	1·21	18	·02
13	·03	July, 1	1·01	19	2·00
16	1·57	3	1·32	20	·36
18	1·12	8	3·08	21	·06
19	·28	10	·38	23	·58
20	·05	11	·29		

The total rainfall during the period of growth was, therefore, 21·71 inches, *i.e.*, there was a daily average of ·47 inches.

No temperature records are available.

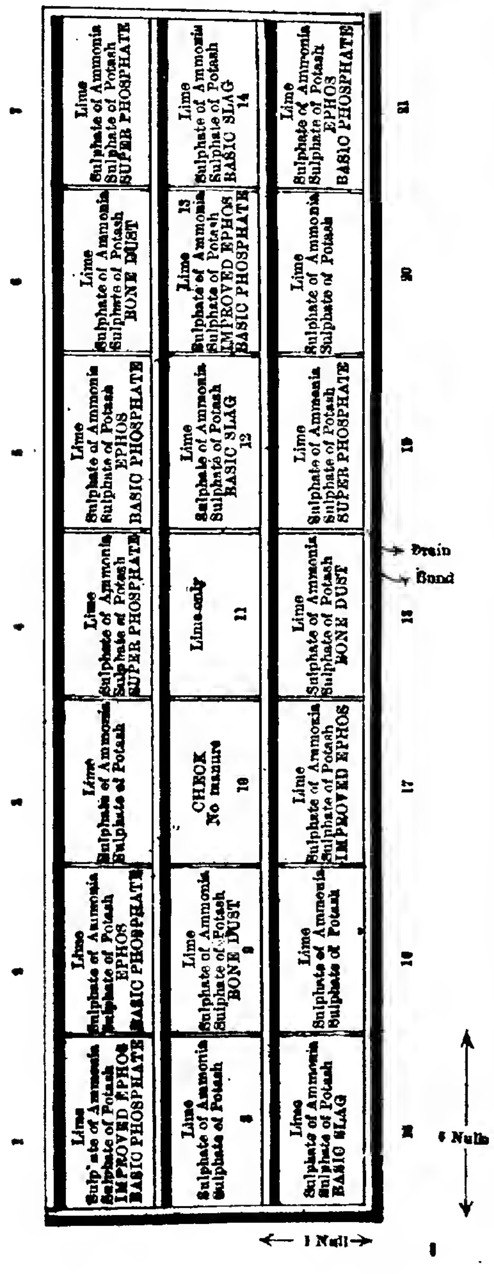
The plots were laid out one null by six nulls as shown in the diagram. The drains were about a foot wide and two feet deep. The plots themselves were perfectly level with the exception of one end of the area where plots Nos. 1, 8, and 15 sloped down gradually. All the manures were applied on Friday, June 8th, and ¾ lb. per plot of cowpea seed was applied on that date and another ½ lb. per plot on Saturday, June 9th. The crops were cut at ground level on July 24th after 46 days' growth and weighed immediately on the spot.

The following table and diagram show the arrangement of the plots and the amounts of the various manures applied on each, and the yields in pounds per plot and tons per acre :—

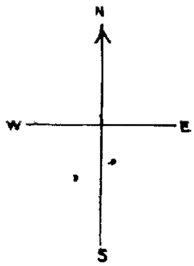
THE GOTOONGA EXPERIMENT.

Manures, applied and rate per acre.	Plot number.	Lb. per plot of green crop.	Average.	Tons per acre of green crop.	Average.
Check. No manure	10	246		5·49	
Lime 800 lbs.	11	264		5·89	
Lime 800 lbs. ... ... Sulphate of ammonia 100 lbs. ... Sulphate of potash 225 lbs. ...	3 8 16 20	322 385 360 317	346	7·18 8·59 8·03 7·07	7·72
Lime 800 lbs. ... ... Sulphate of ammonia 100 lbs. ... Sulphate of potash 225 lbs. ... Ephos Basic Phosphate ...	2 5 21	359 348 350	352	8·01 7·76 7·81	7·86
Lime 800 lbs. ... ... Sulphate of ammonia 100 lbs. ... Sulphate of potash 225 lbs. ... Improved Ephos Basic Phosphate	1 13 17	350 358 379	362	7·81 7·99 8·46	8·09
Lime 800 lbs. ... ... Sulphate of ammonia 100 lbs. ... Sulphate of potash 225 lbs. ... Bone dust	6 9 18	371 401 375	382	8·28 8·94 8·37	8·53
Lime 800 lbs. ... ... Sulphate of ammonia 100 lbs. ... Sulphate of potash 225 lbs. ... Superphosphate	4 7 19	402 413 388	401	8·97 9·21 8·66	8·95
Lime 800 lbs. ... ... Sulphate of ammonia 100 lbs. ... Sulphate of potash 225 lbs. ... Basic slag	12 14 15	412 404 394	403	9·19 9·01 8·19	8·79

Plan of Gotoonga Experiment.



SCALE {Horizontal 1 inch = 24 ft.
Vertical 1 inch = 72 ft.



Immediately before the cowpeas were cut, it was not easy to see any great obvious differences in the appearance of the crops ; they all looked excellent, and the colour of the leaves was a dark healthy green. It was noticeable that just alongside the bunds the green crops were heavier than elsewhere, and this cannot at present be explained. At this point certainly, and not elsewhere, a small amount of subsoil may have been spread over the surface, but at the time of observing this phenomenon it did not occur to us that this could have accounted for the increase in size of the green crop plants on these places. Most subsoil in this district appears to be more or less toxic in its effect on tea when first brought to the surface.*

On looking at the figures of crop returns it will be seen that there is no evidence of any great difference in the initial fertility of the different plots. This can be seen from examination of the figures for any set of plots manured alike. The figures for any one set do not agree absolutely, though they do so fairly well in this particular experiment, but, if the direction in which improvement in the fertility of the soil, as indicated by the figures for any one set of plots manured alike, be noted, it will be found not to agree with the direction indicated by the figures from any other set of plots treated all alike in any other way, showing that the differences are not due to a definite falling off in fertility in any one direction.

For instance, the three figures representing the yield of cowpeas on the superphosphate plots indicate that the soil may be more fertile at the north-easterly end of the plots than at the south-westerly, but the figures of yields from the plots all treated alike with lime, sulphate of ammonia, and sulphate of potash only, indicate exactly the opposite. We can assume, therefore, that the value of the soil of this experimental area was about the same throughout the plots.

The variation between the yields of sets of plots receiving the same treatment was less in these experiments than in those carried out at Sangsua and at Boisahabi.

* Mr. Chapman, Scientific Officer to the Jokai Tea Co. informs us that he has often seen cases of subsoils having a beneficial influence on the growth of leguminous plants when brought to the surface. This phenomenon will receive further investigation.

The following table gives the greatest percentage deviation from the mean of the yields of each set of plots, each plot in which received similar treatment :—

THE GOTOONGA EXPERIMENT.

Manure.	Plot number.	Greatest percentage deviation from the mean yield of sets of plots receiving the same manurial treatment.
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash	8	11·2
Lime... ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Ephos Basic Phosphate	2	1·9
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Improved Ephos Basic Phosphate	17	4·7
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Bone dust...	9	4·9
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Superphosphate	19	3·3
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Basic slag	12, 15	2·2

None of these deviations are very great. It is noticeable that the deviation is greatest in the case of the plot receiving no phosphatic manure.

The above facts show that the initial fertility of the different plots was very similar, and we are, therefore, justified in accepting the results of these experiments with considerable confidence.

The next point to notice is the effect of lime alone. Unfortunately only one check-plot, and only one plot manured with lime alone, had been arranged. The percentage increase in crop due to its use is small, amounting only to 7·3%, which is smaller than the percentage deviation shown by one of them from the average yield of the plots manured with lime, sulphate of ammonia, and sulphate of potash only. Consequently, we are not justified in making use of this figure to give a quantitative value to the effect of lime on the growth of cowpeas on this soil. We can only infer that the effect of lime alone is small.

The effect of sulphate of ammonia, sulphate of potash and lime is however great. The figure giving the average yield of the three plots manured in this way shows an increase of 40·6% above the unmanured plot, and an increase of 31% above the plot manured with lime alone. From the figure 40·6% representing the increase above the check-plot due to lime, sulphate of ammonia, and sulphate of potash, we obtain (by subtracting the figure 7·3%, representing the increase above the check-plot due to lime alone) the figure 33·3% which represents the increase above the check-plot due to the sulphate of ammonia and sulphate of potash.

The following table gives these figures and similar figures for the plots treated with phosphatic manures, expressing the increases as percentages calculated with respect both to the check-plot and to the plot which received the preliminary treatment with lime, sulphate of ammonia, and sulphate of potash only :—

THE GOTOONGA EXPERIMENT.

Manures.	Average increase per cent of yield of the manured plots over that of the check-plot.	Average increase per cent of the yield of sets of plot receiving phosphatic manures over average yield of plots which received lime, sulphate of ammonia, and sulphate of potash only.
Lime	7·3	......
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash	40·6	......

THE GOTOONGA EXPERIMENT—(*continued.*)

Manures.	Average increase per cent of yield of the manured plots over that of the check-plot.	Average increase per cent of the yield of sets of plots receiving phosphatic manures over average yield of plots which received lime, sulphate of ammonia, and sulphate of potash only.
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Ephos Basic Phosphate	43·1	1·7
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Improved Ephos Basic Phosphate ...	47·1	4·6
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Bone dust	55·2	10·4
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Superphosphate	63·0	15·8
Lime ... ... Sulphato of ammonia ... ... Sulphate of potash ... ... Basic slag	63·8	16·4

It will be seen that the total effect of the phosphatic manures is not so great as that of the preliminary treatment with lime, sulphate of ammonia, and sulphate of potash, and it will be noticed also that, of the phosphatic manures experimented with, basic slag and superphosphate give the best results, followed by bones, Improved Ephos Basic Phosphate, and ordinary Ephos Basic Phosphate, which last has had very little, if any, effect at all.

THE BOISAHABI EXPERIMENT.

Boisahabi Division of the Jhanzie Tea Association is situated about 24 miles east of Jorhat near the old road called the Dhodhali.

The land on which these experiments were made is a slightly undulating plateau, well raised above rice-field level. It had once been under tea which has now been abandoned.

The soil here is a close reddish loam and appears to be heavier than that of the two other experimental areas. The manager describes it as "a fairly stiff reddish loam which has the appearance usually associated with a subsoil almost to the surface, only some 2 or 3 inches of the top being darker in colour." The following are mechanical analyses of two samples of surface soil taken one from each end of the experimental area. These analyses show the soil to be a rather closely compacted silt, very similar mechanically to the heaviest sub-type found in the Jorhat district.

BOISAHABI.

Mechanical Analyses.

Calculated on soil dried at 100°C.

Soluble in dilute acid ...	0·42	0·90
Coarse Sand	1·21	1·93
Fine Sand	30·17	32·75
Silt	31·40	26·98
Fine Silt	22·76	23·48
Clay	10·55	10·53
Loss on ignition	3·16	3·18
Total ...	99·67	99·75

These soils contain ·027% and ·031% respectively of phosphoric acid, the citric acid soluble phosphoric acid being ·004% in both cases. The citric acid soluble potash is ·015% and ·020% respectively.

The land on which this experiment was made had previously been under tea, which has now been abandoned.

The average yearly rainfall recorded on this estate is about 83 inches. The rainfall this year has been slightly higher than usual, 86 inches having been recorded up to October 8th. The

daily rainfall, and maximum and minimum temperatures recorded during the time that the cowpeas were growing were as follows:—

Date.	Rainfall.	Maximum Temperature.	Minimum Temperature.	Date.	Rainfall.	Maximum Temperature.	Minimum Temperature.
June, 1 ...	2·37	88	76	June, 25 ...	0·76	87	81
2 ...	......	82	77	26 ...	......	86	80
3 ...	......	...	...	27 ...	0·32	83	79
4 ...	0·38	85	77	28 ...	0·30	87	78
5 ...	......	84	77	29 ...	1·63	88	77
6 ...	0·08	83	78	30 ...	0·94	86	77
7 ...	......	84	77	July, 1 ...	0·03	88	80
8 ...	0·12	79	76	2 ...	0·78	88	76
9 ...	0·77	85	76	3 ...	1·70	88	76
10 ...	0·08	83	78	4 ...	0 05	84	76
11 ...	0·46	83	78	5 ...	0·57	87	79
12 ...	0·24	85	77	6 ...	0·05	87	80
13 ...	......	85	80	7 ...	......	88	81
14 ...	0·06	88	80	8 ...	2·66	86	80
15 ...	0·45	85	79	9 ...	0·87	85	80
16 ...	2·92	86	76	10 ...	2·06	87	79
17 ...	1·88	82	77	11 ...	0·37	87	80
18 ...	0·25	82	78	12 ...	1·48	85	79
19 ...	0·04	87	77	13 ...	1·38	85	79
20 ...	0·06	86	79	14 ...	0·28	85	79
21 ...	......	86	80	15 ...	3·48	83	78
22 ...	1·48	85	80	16 ...	......	85	80
23 ...	......	86	80	17 ...	0·23	87	79
24 ...	0·24	86	80				

The total rainfall during the period of growth was, therefore, 31·82 inches, *i.e.*, there was a daily average of ·68 inches.

It will be seen that there was a rainfall of about 2½ inches the day the seed was sown, and lime, sulphate of ammonia, and sulphate of potash applied.

The plots were laid out two nulls by three nulls and were so arranged as to have three plots in a line, the beds in that direction being three nulls in length, and six plots in a direction at right angles, the breadth in that direction being two nulls. The diagram shows the arrangement of the plots.

Plan of Boisahabi Experiment.

N E W S

2 Nulls →

Lime Sulphate of Ammonia Sulphate of Potash EPHOS BASIC PHOSPHATE 1	Lime Sulphate of Ammonia Sulphate of Potash 2	Lime Sulphate of Ammonia Sulphate of Potash SUPER— PHOSPHATE 3	Lime Sulphate of Ammonia Sulphate of Potash BONE DUST 4	Lime Sulphate of Ammonia Sulphate of Potash BASIC SLAG 5	Lime Sulphate of Ammonia Sulphate of Potash 6
Lime Sulphate of Ammonia Sulphate of Potash BASIC SLAG 12	Lime Sulphate of Ammonia Sulphate of Potash INDOFOS 11	Lime Sulphate of Ammonia Sulphate of Potash BASIC SLAG 10	No manure CHECK PLOT 9	Lime Sulphate of Ammonia Sulphate of Potash IMPROVED EPHOS BASIC PHOSPHATE 8	Lime Sulphate of Ammonia Sulphate of Potash BONE DUST 7
Lime Sulphate of Ammonia Sulphate of Potash SUPER— PHOSPHATE 13	Lime Sulphate of Ammonia Sulphate of Potash BONE DUST 14	Lime Sulphate of Ammonia Sulphate of Potash EPHOS BASIC PHOSPHATE 15	Lime Sulphate of Ammonia Sulphate of Potash SUPER— PHOSPHATE 16	Lime Sulphate of Ammonia Sulphate of Potash 17	Lime Sulphate of Ammonia Sulphate of Potash EPHOS BASIC PHOSPHA 18

Drain

SCALE { Horizontal 1 inch = 25 ft
Vertical 1 inch = 15 ft.

The plots were situated on land sloping downward from north-west to south-east. They were well-drained, and there is no reason why the moisture conditions of the different plots should have differed, except that possibly the plots at the bottom of the slope had had fine soil washed on to them previous to the experiment, though the lowest plots *i. e.*, Nos. 17 and 18 were not at the foot of the slope.

During the course of these experiments *i. e.* on June 25th the manager reported as follows :—

"Numbers 3, 13, and 16 easily best :

Numbers 5, 10, and 12 second best : Very healthy : Not quite so even :

Numbers 4, 7, 8, 11, and 18 about even : Healthy but not so well grown :

Number 6 about equal to above, but not quite so well grown :

Numbers 14, 15, and 17 even and healthy, but grown rather poorer than previous lot :

Number 1 poorer growth, uneven but healthy :

Number 2 poorer growth, but looks as if one end had another manure by mistake :

Number 9 Check : Easily the worst but the germination is good :

All show nice healthy crops though the colour of the better plots is darker. The germination is not altogether even but this can hardly be placed to the manure although it is significant that the check plot has perhaps as even a lot of plants as the best of the others.

Numbers 4, 7, 8, 11, and 18 are all rather uneven in germination."

The plots looked fairly even just before cutting, their appearance being slightly less even than the Gotoonga plots, and very much more so than the Sangsua plots.

All the manures except the phosphatic manures were applied on Friday, June 1st, and the seed which consisted of $\frac{3}{4}$ lb. of white

seed mixed with $\frac{1}{2}$ lb. fawn seed was sown on that date at the rate of $1\frac{1}{4}$ lbs. per plot, *i. e.* $31\frac{1}{4}$ seers per acre. The phosphatic manures were applied on June 7th. The crops were cut at ground level on Tuesday, July 17th, after 46 days' growth and weighed immediately on the spot.

The following table and diagram show the arrangement of the plots and the amounts of the various manures applied on each and the yields in pounds per plot and tons per acre :—

THE BOISAHABI EXPERIMENT.

Manures applied and rate per acre.	Plot number.	Lb. per plot of green crop.	Average.	Tons per acre of green crop.	Average.
Check. No manure	9	151		3·37	
Lime 800 lbs. ... ... Sulphate of ammonia 100 lbs. ... Sulphate of potash 225 lbs. ...	2 6 17	214 218 176	202	4·82 4·58 3·92	4·44
Lime 800 lbs. ... ... Sulphate of ammonia 100 lbs. ... Sulphate of potash 225 lbs. ... Ephos Basic Phosphate	1 15 18	254 214 302	256	5·66 4·77 6·74	5·72
Lime 800 lbs. ... ... Sulphate of ammonia 100 lbs. ... Sulphate of potash 225 lbs. ... Improved Ephos Basic Phosphate	8	294		6·56	
Lime 800 lbs. ... ... Sulphate of ammonia 100 lbs. ... Sulphate of potash 225 lbs. ... Bone dust	4 7 14	292 319 252	288	6·51 7·12 5·62	6·42
Lime 800 lbs. ... ... Sulphate of ammonia 100 lbs. ... Sulphate of potash 225 lbs. ... Superphosphate	3 13 16	332 312 336	326	7·41 6·96 7·50	7·29
Lime 800 lbs. ... ... Sulphate of ammonia 100 lbs. ... Sulphate of potash 225 lbs. ... Basic slag	5 10 12	324 328 318	324	7·67 7·32 7·09	7·36
Lime 800 lbs. ... ... Sulphate of ammonia 100 lbs. ... Sulphate of potash 225 lbs. ... Indofos	11	220		4·01	

It is noticeable in these experiments, as in the case of all the others, that the most even results were obtained on the plots which were receiving the most efficacious phosphatic manures, in this case, as in the others, basic slag, and superphosphate. The deviations shown by Ephos Basic Phosphate, by bone dust, and by lime, sulphate of ammonia, and sulphate of potash only, were considerably greater, as is shown by the following table which gives the maximum deviations, in the case of plots receiving the same manures, of any one plot from the average of the set to which it belongs :—

THE BOISAHABI EXPERIMENT.

Manures.	Plot number.	Greatest percentage deviation from the mean yield of sets of plots receiving the same manurial treatment.
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash	17	12·9
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Ephos Basic Phosphate	18	17·9
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Bones	14	12·5
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Superphosphate	13	4·3
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Basic slag	12	1·9

It will be seen that the deviations on the whole are greater in the case of these experiments than in that of the Gotoonga series. The smallest deviation is here also shown by plots which received the manures which have proved most effective.

In these experiments there was no plot on which the effect of lime alone was tried. Its place was taken by a phosphatic manure called Indofos sold by Messrs. Graham & Co.

The action of sulphate of ammonia, and sulphate of potash with lime is considerable. The figure giving the average yield of the three plots manured in this way shows an increase of 33·7 % above the unmanured plot.

The following table gives the increases of the yields of the manured plots expressed as percentage increase over both the check-plot and the average of the plots which received lime, sulphate of ammonia, and sulphate of potash only.

THE BOISAHABI EXPERIMENT.

Manures.	Average increase per cent of yield of the manured plots over that of the check-plot.	Average increase per cent of the yield of sets of plots receiving phosphatic manures over average yield of plots which received lime, sulphate of ammonia, and sulphate of potash only.
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash	33·7	: :
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Basic slag	114·5	60·3
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Superphosphate	115·8	61·3
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Bone dust	90·7	42·5
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Indofos	45·6	8·9
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Improved Ephos Basic Phosphate ...	94·7	45·5
Lime ... ... Sulphate of ammonia ... ... Sulphate of potash ... ... Ephos Basic Phosphate	69·5	26·7

It will be seen that in this case the total effect of the phosphatic manures is usually greater than that of the preliminary treatment with lime, sulphate of ammonia, and sulphate of potash alone. All of the phosphatic manures are distinctly effective. Basic slag and superphosphate have about the same effect, and they give the best results, the addition of one or other of these substances to the sulphate of ammonia, sulphate of potash and lime more than trebling the crop. The value of the other manures is in the following order :—Improved Ephos Basic Phosphate, bones, Ephos Basic Phosphate, and Indofos.

The Sangsua Experiment.

Sangsua Division of the Moabund Tea Company is situated about 3 miles to the west of Gotoonga and further away from Jorhat.

The soil of this tract of country is on the whole lighter than that of Gotoonga, but it appears to be slightly heavier than the soil of the particular piece of land used for the Gotoonga experiment. It is of a reddish colour. It is described by the manager as being light, friable, and loamy. The following are mechanical analyses of two samples of this soil taken one from either end of the experimental area.

Sangsua.

Mechanical Analyses.

Calculated on soil dried at 100°C.

Soluble in dilute acid ...	0·45	0·41
Coarse Sand	7·44	1·68
Fine Sand	55·30	51·28
Silt	14·24	19·51
Fine Silt	8·30	16·91
Clay	10·03	5·62
Loss on ignition	4·26	4·93
Total ...	100·02	100·34

These soils both contain ·097% of phosphoric acid, the available phosphoric acid being ·007% and ·008% respectively. The citric acid soluble potash is ·916% and ·020% respectively.

These analyses show a great resemblance to those of the Gotoonga experimental area, the soil of the latter place being however slightly the lighter of the two.

These experiments were carried out on grass land on which tea had never been planted. The land was more level here than in the case of either of the other series of experiments, and equal care was taken in preparing the plots. Yet curiously enough a very marked difference in the fertility of the soil was apparent at different parts of the experimental area.

The average yearly rainfall recorded on this estate is about 80 inches. The daily rainfall and maximum and minimum temperatures recorded during the time that the cowpeas were growing were as follows :—

Date.	Rainfall.	Maximum Temperature.	Minimum Temperature.	Date.	Rainfall.	Maximum Temperature.	Minimum Temperature.
June, 18 ...	·31	90	80	July, 10 ...	·25	89	78
19 ...	·05	90	80	11 ...	·08	87	79
20 ...	......	94	81	12 ...	·73	89	79
21 ...	·25	91	81	13 ...	·11	88	80
22 ...	......	91	81	14 ...	1·10	89	79
23 ...	·34	90	80	15 ...	·03	87	80
24 ...	·13	90	80	16 ...	·05	86	80
25 ...	·48	90	80	17 ...	......	85	80
26 ...	......	86	80	18 ...	1·20	89	80
27 ...	·09	91	78	19 ...	·09	87	80
28 ...	1·72	88	78	20 ...	·03	89	79
29 ...	1·55	88	78	21 ...	......	88	80
30 ...	·20	90	80	22 ...	·86	89	79
July, 1 ...	2·12	90	78	23 ...	·09	85	78
2 ...	3·14	88	77	24 ...	......	85	78
3 ...	......	86	78	25 ...	·10	88	79
4 ...	......	89	79	26 ...	......	87	80
5 ...	·14	87	81	27 ...	·13	91	81
6 ...	·20	90	81	28 ...	......	89	80
7 ...	1·67	89	80	29 ...	......	88	79
8 ...	·38	88	80	30 ...	......	88	80
9 ...	·33	88	81	31 ...	......	86	80

That is to say the total rainfall during the period of growth was 17·95 inches, and there was a daily average of ·41 inches.

Plan of Sangsua Experiment.

1 Null →

ime lphate of Ammonia lphate of Potash PHOS ASIC IOSPHATE 1	Lime Sulphate of Ammonia Sulphate of Potash 2	Lime Sulphate of Ammonia Sulphate of Potash SUPER— PHOSPHATE 3	Lime Sulphate of Ammonia Sulphate of Potash EPHOS BASIC PHOSPHATE 4	Lime Sulphate of Ammonia Sulphate of Potash BONE DUST 5	Lime Sulphate of Ammonia Sulphate of Potash SUPER— PHOSPHAT 6
ime ulphate of Ammonia ulphate of Potash ONE UST 7	Lime only 8	Lime Sulphate of Ammonia Sulphate of Potash BONE DUST 9	Lime Sulphate of Ammonia Sulphate of Potash BASIC SLAG 10	Lime Sulphate of Ammonia Sulphate of Potash IMPROVED EPHOS BASIC PHOSPHATE 11	Lime Sulphate of Ammonia Sulphate of Potash BASIC SLAG 12
ime ulphate of Ammonia ulphate of Potash 13	Lime Sulphate of Ammonia Sulphate of Potash BASIC SLAG 14	No manure Check 15	Lime Sulphate of Ammonia Sulphate of Potash SUPER— PHOSPHATE 16	Lime Sulphate of Ammonia Sulphate of Potash 17	Lime Sulphate of Ammonia Sulphate of Potash EPHOS BASIC PHOSPHAT 18

General direction of decrease in fertility

Direction of decrease in fertility in Basic slag plots.

← 1 Null

SCALE { Horizontal 1 inch = 12 ft.
Vertical 1 inch = 32 ft.

The plots were laid out 1 null by 6 nulls as shown in the diagram. The drains were narrow and about 2 feet deep. The plots were absolutely level throughout and well fenced in. All the manures except the phosphatic manures were applied on Tuesday, 22nd May. The phosphatic manures were applied on the 18th June, and the seed was sown on that date at the rate of $\frac{1}{4}$ lb. per plot broadcasted, i. e. $31\frac{1}{4}$ seers per acre. The crops of cowpeas were cut at ground level on July 31st after 42 days' growth and weighed immediately on the spot.

The following table and diagram show the arrangement of the plots and the amounts of the various manures applied on each and the yields in pounds per plot and tons per acre.

Manures applied and rate per acre.	Plot number.	Lb. per plot of green crop.	Average.	Tons per acre of green crop.	Average.
Check. No manure	15	40			
Lime 800 lbs.	8	102			
Lime 800 lbs.	2	185		4·11	
Sulphate of ammonia 100 lbs. ...	13	78	111	1·74	2·47
Sulphate of potash 225 lbs. ...	17	70		1·56	
Lime 800 lbs.	1	342		7·63	
Sulphate of ammonia 100 lbs. ...					
Sulphate of potash 225 lbs. ...	4	327	317	7·29	7 07
Ephos Basic Phosphate ...	18	281		6·31	
Lime 800 lbs.					
Sulphate of ammonia 100 lbs. ...					
Sulphate of potash 225 lbs. ...	11	352		7·80	
Improved Ephos Basic Phosphate					
Lime 800 lbs.	5	447		9·97	
Sulphate of ammonia 100 lbs. ...	7	446	437	9·95	9·74
Sulphate of potash 225 lbs. ...	9	417		9·30	
Bone dust					
Lime 800 lbs.	3	473		10·55	
Sulphate of ammonia 100 lbs. ...	6	458	457	10·22	10·22
Sulphate of potash 225 lbs. ...	16	441		9·89	
Superphosphate					
Lime 800 lbs.	10	448		10·00	
Sulphate of ammonia 100 lbs. ...	12	468	445	10·44	9·95
Sulphate of potash 225 lbs. ...	14	420		9·41	
Basic slag					

It will be seen from the diagram that the yields of each set of plots manured in the same way fall off in the same direction in

the case of all the manures except basic slag. This direction is indicated by an arrow. The reason for the discrepancy shown by the plot manured with basic slag cannot be explained at present.

With such marked variation in the fertility of the soil from one part of the experimental area to the other, it is impossible to obtain accurate comparison, with each other or with the check-plots, of the effect of the different manures used.

The plot treated only with lime gives an increased yield of 155% above the check-plot, but, owing to the falling off in the fertility of the soil being in the direction in which the check-plot lies with respect to the limed plot, this figure is probably of little value. That this is so is emphasised by the fact that one of the plots which received lime, sulphate of ammonia, and sulphate of potash, *i.e.* plot No. 17, only gives an increase of 78% above the check-plot No. 15 which is only two plots away from it. Also plot No. 13 manured likewise with lime, sulphate of ammonia, and sulphate of potash only, gives an increase of 95% over the check-plot, a figure which is in fair agreement with that given previously with respect to plot No. 17. Plot No. 13 is only two plots away from plot No. 15. This part of the area can obviously only produce a very meagre crop when unmanured, and treatment with lime, sulphate of ammonia, and sulphate of potash alone has a very great influence on the fertility of the soil. Here obviously we have a condition of the soil bordering on such lack of fertility for this particular crop that to grow one at all is almost impossible, but on the application of a minimum quantity of some suitable manure capable of remedying the infertile condition, a crop is immediately produced where no crop to speak of could be grown before. A case similar to this is afforded by the growth of oats in the Government Farm near Jorhat. Oats cannot be grown there until enough lime is applied to correct the acidity of the soil.

In such cases it is futile to pursue calculations derived from experimental plot returns with a view to determining the absolute value of various manures used on a particular soil. For instance, in this case, if we work out the percentage increase of yield of plot No. 14, which received lime, sulphate of ammonia, sulphate

of potash, and basic slag, over the check-plot No. 15, the result shows an increase of 905% and an increase of 438% over plot No. 13 which was manured with lime, sulphate of ammonia, and sulphate of potash only, whereas in the case of superphosphate applied on plot No. 3 alongside plot No. 2 which received lime, sulphate of ammonia, and sulphate of potash only, the percentage increase due to the superphosphate is only 155%. These figures are of course valueless.

All that can be said therefore is, that lime, sulphate of ammonia, and sulphate of potash appear to have considerable influence on the fertility of the soil, but certainly the most effective kinds of manures are phosphatic manures. All the phosphatic manures applied appear to be of considerable value on this soil, although the extent of the action is dependent on some condition of the soil which varies considerably from place to place within even a small space of ground.

We can compare roughly the relative effects of the different phosphatic manures used. Superphosphate, bone dust, and basic slag have given fairly similar results. Whereas the two other phosphatic manures tried have been considerably less effective.

The percentage deviations from the average in the case of sets of plots each plot of which received the same treatment are once again greater in the case of the less effective manures than in the case of the sets of plots which have given the best results.

The manures most effective in producing crop appear also to be most effective in reducing the condition which causes variations in fertility.

A possible explanation of this is that phosphatic manures in even small quantities may be able to neutralise the toxicity which these soils show towards cowpeas. The balance of the manurial applications, after a quantity has been so used up, acts directly as a phosphatic manure. This is a suggestion only and these experiments by no means prove that this theory is tenable, though they suggest it.

Summary and conclusion.

The three series of experiments above recorded are experiments made on similar lines to those carried out at Borbhetta in 1915.

Each of the three series must be considered separately for they were made under conditions not strictly similar in each case, though we endeavoured to make them as closely comparable as possible. They extend our knowledge of the value of different kinds of phosphatic manures for the particular purpose of producing as heavy a green crop as possible (in this case cowpeas) within a period of about six weeks. They confirm the results of the Borbhetta experiments, which showed that phosphatic manures are of great value in improving the growth of green crops, and that a given quantity of phosphoric acid applied in the form of basic slag or superphosphate gives sensibly similar results, results which are considerably better than those obtained by applying the same quantity of phosphorie acid in the form of bones, Ephos Basic Phosphate, Improved Ephos Basic Phosphate, and Indofos.

A very striking fact in connection with these experiments is that in the case of the Boisahabi and the Gotoonga experiments, which were carried out on abandoned tea land, the effect of phosphatic manures is very much less than in the case of the Borbhetta and Sangsua experiments, which were carried out on grass-land. The increases, however, due to the preliminary manuring with lime, sulphate of ammonia, and sulphate of potash were very much greater in the case of the Boisahabi and the Gotoonga than in the case of the Sangsua and Borbhetta experiments. If this distinct difference in the effect of phosphatic manures according as they are used on land which has been for many years under tea or on land that has recently been under grass, turns out to be a fact of general occurrence throughout the North-East Indian tea districts, or even if it is found to hold good for one or more widely distributed type of soil, it throws considerable new light on our manuring problems.

Another interesting fact to be noted in connection with all these experiments is that the deviation from the average result of several plots all treated to the same manurial application is less when an effective phosphatic manure is part of the treatment than when a less effective phosphatic manure is used or when no such manure is used at all. This suggests that inequalities in the fertility of soils may be due to a toxic substance which is rendered ineffective by a comparatively small quantity of any phosphatic manure the

general action of which on these soils indicates ready availability, *e.g.*, superphosphate. In such cases a portion of the manurial application would be required to remove the toxin and the remainder would act directly as a phosphatic manure. If we assume, and there is considerable evidence in support of this, assumption, that close-grained soils are more liable than light soils to harbour this toxin, this would partly explain the greater effectiveness of phosphatic manures on the Boisahabi than on the Gotoonga soils. Another and possibly more direct explanation is, however, suggested by the respective figures for the total and available phosphoric acid on these soils, and the higher daily rainfall in the case of the Boisahabi experiments may have been a factor of importance.

The results of these experiments show the importance of the soil factor within even a comparatively restricted area of country, and emphasise the desirability of carrying out further comparative experiments of this kind on tea soils which show much wider differences in type.

G. D. H.

CULTURAL CONTROL

BY

E. A. ANDREWS, B.A.

When a man first hears the buzz of a mosquito at the beginning of the rains his immediate impulse is to catch it and slay it. As the numbers of the insects increase he finds this task too arduous, and sends to Calcutta for the wherewithal to smell them out. This proving ineffective, he either gives the fight up as hopeless, and retires within a mosquito-proof room, or turns his attention to his bungalow compound and its surroundings, with the idea of eliminating possible breeding-places. The most obvious, and the most sensible thing to do is left until last—not only so, but until the time when the location and eradication of these places is most difficult. Why is this ? Whatever be the cause, it is impossible to deny the fact that in a great number of instances the remedy which lies closest at hand, and is easiest to apply, is left untried until all others have failed.

And the same is true where the control of insect pests of crops is concerned. Many an instance has occurred where a cultivator has sent for insecticides to spray a crop attacked by caterpillars, and bewailed the fact that it did not arrive until after the caterpillars had gone, when, had he but known or thought of it, those same caterpillars were comfortably reposing in the chrysalis state just beneath the surface of the ground, where the majority of them could have been killed by putting in a hoe. Or again, to take the same instance, the insecticide may have been applied, and the caterpillars have disappeared shortly after. In such a case the insecticide gets the credit for their disappearance, whereas they have probably gone below ground as in the ordinary course of events, and are being allowed to mature and lay the foundation of a second and perhaps more serious attack later on, when the same insecticide will be applied again, and so it will go

on until it happens that a hoe is put into the area, entirely by accident, at a time when the chrysalides are below ground. This checks the pest for a time, and if the insecticidal treatment has not been abandoned by that time it is pronounced to be successful. Should it have been abandoned, the cessation of attack is looked upon as curious for a time, and then probably forgotten.

This article is a plea for a little closer attention to, and a fuller utilisation of, what may be called "cultural" methods of insect control, that is, the organisation of the ordinary garden operations in such a way that they may exert their maximum effect in keeping down insect pests in general, or any insect pest in particular. It is not possible, nor is it necessary, in an article of this nature, to describe in detail the life history of every pest of tea, and the way in which garden operations can exert a controlling influence on each. A good deal of information with regard to the first-mentioned can be obtained from the publications of this department, which are accessible to every planter, while the second will readily suggest itself to any man with an intelligent appreciation of the pest he is dealing with and with a knowledge of local conditions. The most one can do here is to outline the general principles of cultural control, giving particular instances here and these as illustrations.

Take the case of a new clearance. The land is cleared, burnt, hoed, the young bushes planted. The plants must be allowed to get a firm hold before much more in the way of deep hoeing can be done. Labour is never too plentiful, and is wanted in the bearing tea, so cultivation is usually limited to hoeing the plants out of jungle occasionally. In many cases they are, perhaps, merely kept clean by forking round them. When a hoe is put in, in the cold weather, and the plants can be properly seen, the leaves will probably be found to be riddled with holes. The next year more cultivation is given, the next year still more. Year by year the jungle is brought more under control. Year by year the holes in the leaves become less noticeable. Why is this? The holes are made, for the greater part, by small beetles. These beetles spend the early part of their existence as grubs, living just below the ground or amongst the roots of the grass. Year by year there is a

large mortality amongst them owing to the repeated hoeing, and finally their numbers become so small as to be comparatively negligible. No more effective, cheaper, or less troublesome means of dealing with them could have been devised. Most of our pests are not so easily controlled as this, but the value of a good hoe, put in at a time when the insect is in a stage at which it lives in the soil, cannot be overestimated. Beds prepared for the reception of seeds are well pulverised for many and obvious reasons, but one good result of this, from the point of view of insect control, can be seen in the small proportion of beetle-riddled leaves seen in a nursery, as compared with what is to be found in a clearance.

Cultivation, besides being of direct value in killing out insect pests or exposing them to the action of uncongenial conditions and the attacks of enemies, is of indirect value in many ways, particularly in certain soils. A hoe often stimulates the bushes and helps them to throw off an attack, as has been found repeatedly in the case of the tea mosquito and red spider, and occasionally in the case of green fly and thrips, and a trench hoe sometimes does a great deal of good in this way. Recently a case was experienced of an area of comparatively young tea, planted in soil which contained a large proportion of fine particles, suffering severely from red spider, though it had been well drained and trenched in the previous cold weather. The attack of red spider was late in coming on, but very severe, and it was found that a new pan had formed, since the previous trenching and during that one season, just below the limit of depth of the light hoe, owing to the fine particles having been washed down through the cultivated surface layer. The area was again trenched, to a depth of nine inches, in place of the next light hoe, and the treatment produced a great improvement. By the breaking of the newly-formed pan, the excess water was allowed to get away from the surface feeding rootlets, with a consequent restriction to well-drained conditions, and lifting of the red spider. Such a form of control, which is inexpensive, easy to carry out properly, and removes the cause of the liability of the bushes to attack is surely more satisfactory than to resort to expensive insecticides, which can seldom be applied thoroughly, and which, at the same time, do nothing to alter the conditions which render the

bushes constantly liable to attack ? One would emphasize here that one does not mean to discount the value of insecticides. Far from it. One merely wishes to point out the great value that cultural methods of control can be and are in assisting in the fight against insect pests. Forking, and thullying round the bushes, are two of the minor forms of cultivation which help in the good work, especially when the coolies are encouraged to collect any grubs, chrysalides, etc., that they may find.

Proper drainage is another thing which has a great influence on the liability of bushes to attack by pests, the tea mosquito and red spider being two cases in point.

Manuring is not without its effect on the liability of bushes to attack. Injudicious manuring has probably been the cause of more trouble in this way than has been suspected. A too prolonged course of nitrogenous manures alone is known to render plants more liable to disease, and schemes of manuring which increase the acidity of the soil may, if carried too far, result in bad attacks of red spider and such like pests. Haphazard manuring is to be deprecated, and only such manuring schemes should be carried out as are based on an adequate knowledge of the requirements of the soils to be treated.

The pruning season is a time during which much good or harm can be done, and it is a noticeable feature of the tea districts, speaking generally, that where the work done in this respect is good, the bushes suffer less from insect attack than in districts where the work is indifferent. Labour problems, of course, affect this operation very considerably, and very few planters are able to prune as well as they would wish to. Much has been already written on the subject of careful pruning, but, at the risk of being tedious, one would like to recapitulate the main points which can influence insect attack. The first and foremost of these is the avoidance of snags. Snags mean dead wood. Dead wood means borers and white ants. The avoidance of snags will not bring about the extinction of either, but it does mean an enormous reduction in the number of vulnerable places in the bush. Dead twigs and branches, for similar reasons, should always be removed. Prunings

should not be allowed to lie in the bushes if it can possibly be avoided. Many caterpillars pupate in the centre of a bush if they can get cover. Many insects which would otherwise go to the ground for shelter, where they are always liable to be destroyed by a fork or hoe, find a harbour of refuge, when prunings are left in the bushes, where they can lie undisturbed. Moisture collects in such masses of decaying vegetation, and conduces to the growth of mosses and lichens, which in turn afford shelter and congenial surroundings to scale insects and mites. For similar reasons, stems badly affected by termites, borers, or bark-eaters, should be removed as far as possible. None of these measures will prevent attack, but, carefully carried out, they do much to mitigate it.

Such in brief outline are the principles of cultural control of insect pests as we believe them to apply to tea garden work. We have done but poor justice to the importance of the subject, but if it can but induce planters to experiment a little more with the powerful weapon they have ready to hand, this article will have achieved its object.

THE DISSEMINATION OF PARASITIC FUNGI.

Part I.

The following is a series of extracts from "The dissemination of parasitic fungi and international legislation" by Dr. E. J. Butler, Imperial Mycologist, Memoirs of the Department of Agriculture in India, Botanical series, 1917.

The subject is of great importance to the tea industry and it should be carefully studied.

Owing to lack of space we are only able here to give the extracts containing Dr. Butler's views on the dissemination of fungi. The numerous examples he mentions and his discussion of the Rome Convention have had to be omitted :—

"A fungus is a minute plant, composed of a vegetative part (mycelium) and seed-like reproductive bodies (spores). It may be disseminated by the mycelium or by spores, and in no other way.

The mycelium is incapable of independent spread for any considerable distance, except in rare cases: it is usually adherent to the substance on which it grows, often immersed wholly or in part in it; small fragments detached perish quickly; and larger pieces, which might preserve their vitality, fall to the ground before long when carried into the air. Just as it is well known that in the higher plants the vegetative body is less able to stand extremes of heat and cold or dryness than the seeds, so also in the fungi the mycelium is generally less resistant to such unfavourable conditions than the spores. Laboratory workers who are engaged in the cultivation of living fungi are familiar with this fact. Furthermore the fungi which cause disease in plants are parasites and for the most part cannot long survive in their vegetative condition (unlike the spores) unless able to obtain living food from the plants on which they grow.

Hence, dissemination over long distances in the mycelial condition only occurs when the substance on which the fungus is growing is itself conveyed from one place to another; in the case of parasites such dissemination is practically confined to occasions when the plants* on which they feed are moved, though a few cases, such as facultative soil parasites, may travel with earth or the like. Nevertheless several instances of extensive spread in this manner are known—

Phytophthora infestans (the cause of the potato blight) has reached practically all parts of the world, in which potatoes are grown, as an internal mycelium within the potato tuber.

The blister-rust of white pines (*Peridermium strobi*) has been introduced into the United States as an internal mycelium in the stems of seedling pines obtained in vast numbers from Europe.

The mildew of *Euonymus japonicus* survives the winter in Europe as an external mycelium on the leaves, and doubtless came from Japan or elsewhere in this condition, when first introduced into Europe some 15 years ago.

The spores are, however, the usual means of spread. For this they are much better fitted than the mycelium, being often long-lived bodies, able to stand drying or extremes of heat or cold. The spores of bunt of wheat have been germinated after 8 years, and have been kept in a solid lump of ice for 3 months in Canada, without the slightest injury, though the temperature fell to 20° F. more than once. They are more susceptible to heat: bunt spores can be killed by immersing them in hot water at about 130° F. for 10 minutes and yellow rust of wheat in India by 5 minutes in water at about 120° F.; the dry spores can stand considerably higher temperatures. So far from being injured by drying they can usually be best preserved in a dry condition and it has often

* Living plants are taken to include not only complete plants, but also cuttings, buds, tubers, bulbs, seeds, and any other part that can survive detachment from the plant, even (within limits) cut flowers and green leaves. Some parasitic fungi can also survive in a vegetative and often quite long-lived condition on dead parts of plants.

been noticed that thorough drying favours their subsequent germination.* Owing to their small size also, often approximating to that of very fine dust, they are readily blown about, and as they are usually detached as soon as ripe, air currents play the most important part in their dissemination. Many spores are provided with arrangements for sticking them to objects with which they come into contact. Thus many rusts and smuts have fine spines on the spore wall, the anthracnoses liberate their spores with a mucilaginous substance which is adhesive on drying, the cilia of *Pestalozzia* serve the same purpose, and so on. Not only, therefore, are spores cast into the air in vast numbers,† but their small size and tendency to adhere cause them to attach themselves to neighbouring objects such as other plants, insects which visit plants, and even the person and implements of people passing through infected fields or working in them.‡

These properties of the spores render them peculiarly suited for dissemination. For short distance spread, currents of air are unquestionably the most important means in the great majority of cases. The splashing of rain, accompanied by the flapping of wet leaves against one another, is the chief means in a few cases, as in the bean anthracnose, and is a secondary means in others, as in potato blight. Adhesion by contact is well known to cause much of the bunt in wheat, when wind-borne spores or broken bunt balls get into the seed grain. Spread by insects takes place in certain well-established cases, and is highly probable in others. The ergots

* There are some exceptions to this, as the 'summer spores' (sporangia) of the downy mildews, which are often unable to survive even after 24 hours' thorough drying.

† It has been estimated that a small spore horn of the chestnut bark disease fungus (*Endothia parasitica*) may contain 115 million spores, a bean pod affected with the bean anthracnose (*Glomerella Lindemuthianum*) may produce from 500 to 1,000 million spores during the season, while *Lycoperdon bovista*, one of the (harmless) puff balls, may contain 7,000,000,000,000, and the common edible mushroom can shed spores at the rate of 40 millions per hour.

‡ In the Southern States it is said that experience has taught the peril of working in the bean fields attacked by anthracnose on wet days, owing to the way the disease is carried on the person and implements of the workers. We have evidence, too, that the Godavari palm disease in India is often carried by those who climb the trees for the leaves, fruit and for toddy drawing.

of rye (*Claviceps purpurea*) and other grasses are carried in part by *Melanostoma mellina*, *Rhagonycha fulva*, etc., which are attracted by the sugary secretion that accompanies the *Sphacelia* stage of the fungus, and carry the spores to other grass flowers. Pear blight, [*Bacillus* (*Micrococcus*) *amylovorus*] begins often in the stigma, to which the bacillus is carried by insects (chiefly bees) from infected sap escaping from the bark in spring. In *Sclerotinia urnula* also the sweet-smelling spores are carried by insects to the flowers of *Vaccinia Vitis-idaea* (cow-berry). In many cases insects which cause wounds allow parasitic fungi to enter ; larch canker may begin from the wounds of *Coleophora lariciella* and *Chermes laricis* ; *Ceratostomella pilifera* (a fungus which causes blueing of the wood of *Pinus ponderosa*) from wounds of *Dendroctonus ponderosæ* and so on ; while the *Nectrias* which cause canker of fruit and forest trees are said sometimes to be conveyed on the bodies of the insects which cause wounds through which the fungi can enter. Occasionally other animals have been accused of disseminating disease ; mice are said to carry the spores of *Fomes annosus*, the cause of a well-known pine disease, and snails those of a fir disease caused by *Cucurbitaria pityophila*. Almost any disease may be carried by farm-workers, but the cases of serious damage from this cause are rare. All soil-inhabiting fungi are liable to be carried by irrigation water or surface wash after heavy rain ; *Fusarium* wilts are undeniably carried from field to field by the latter ; and there is evidence in India and elsewhere that diseased sugarcane stems thrown into irrigation channels may enable the spores of the red rot fungus to reach crops growing at a lower level. Infected soil may also carry the spores of the fungi which cause wilt and allied diseases and may reach other fields in various ways, as on the boots of field-workers and pedestrians. But the majority of these and other minor means of dissemination can only be invoked to account for spread over comparatively short distances and may be at once ruled out as probable causes of extension of disease to distant countries. Leaving out dissemination through the air, all the others require the susceptible plant to be within short range of the source of infection. The normal flight of insects, the flow of irrigation water, or the range of labourers and

pedestrians, is through a limited area ; and though we could imagine diseases crossing land frontiers or even passing, say, from Ireland to England in this manner, spread to Europe from America or East Asia would be rare indeed.

For such long-distance spread, for what may be called "discontinuous spread," the methods are much fewer. They may practically be reduced to three : dissemination through air ; dissemination by animals that travel long distances rapidly, as migrating birds and certain insects ; and dissemination on plants and other horticultural produce. The relative importance to be assigned to each has not, so far as I know, ever been adequately discussed and exact data for such a discussion are scanty ; yet they yield results of considerable significance.

To take what must be of the least importance first, birds are probably the chief animals that could materially contribute to the discontinuous spread of parasitic fungi. The distances to which they travel are remarkable. Richard's Pipit, which breeds in Eastern Siberia from Lake Baikal to the sea of Okhotsk, regularly visits Europe, as far sometimes as England, and passes through Spain even to Western Africa. Several other Siberian birds visit Western Europe, some, such as the Hooded Crow, in enormous numbers. The Knot, which breeds within the North Polar basin, has been found in winter in Australia and New Zealand. Individually marked storks, which breed in Central Europe, have been identified in South Africa in winter. Still it is perhaps possible to show that they cannot be a serious danger. The wanderings of migratory birds which travel long distances are usually between areas of very dissimilar climate : they pass in a general direction from north to south and back again ; and between the extremes of their journeys the climates and vegetation are so different that the agricultural and horticultural products are usually sufficiently distinct to have very few parasites in common. Where birds pass through areas with partially similar agricultural and horticultural crops, as from south to north Europe and the southern to the northern parts of North America, the parasites which they could convey would sooner or later be able to effect continuous spread by one or other of the methods discussed above ; for the most part

they have already done so, where not restricted by deficient powers of acclimatisation, and though migrating birds may have enabled them to pass natural barriers such as the Alps or the Channel more rapidly, the present distribution would probably be much the same even if birds did not exist. The parasites of plants long established in southern and northern Europe are, except in the case of those recently introduced, probably as much identical as they are ever likely to be. Where they differ, the explanation is to be sought in the lesser adaptability to differences in climate frequently possessed by the parasites as compared with their (cultivated) host plants.* In general it may be said that England, for instance, is little liable to receive new pests from southern Europe except when they have been recently introduced into the latter area. The danger, in England, is primarily from more distant regions where the climate is not too dissimilar, such as North America and to a considerable extent also temperate eastern Asia, and birds or other animals cannot greatly increase this danger.

There is probably an exception in the case of recently introduced pests. Certain classes of these might be rapidly spread within a large part of Europe by birds. Nothing can reduce this danger, but we may console ourselves by the reflection that continuous spread through the same areas would almost certainly occur in any case in the long run, and that the remedy lies in keeping such pests out of Europe altogether, by international co-operation.

Exact investigations of the extent to which birds can actually disseminate fungi seem to be very scanty. In the eastern United States some were examined a short time ago.† They were shot, and the beaks, legs, etc., scrubbed, the washings being then used to determine the number of spores. On two woodpeckers, 757,074 and 624,341 spores, respectively, were found, and a high proportion of these were the spores of the chestnut bark disease, which is at present exterminating the chestnut in this area. Some of the birds shot were on their northward migration and could no doubt have

* Nothing else will explain the absence of *Phytophthora infestans* in potatoes in the warmer and drier parts of the United States and in the centre and west of India, or of wheat bunt and maize smut in all but the most temperate parts of India.

† *Journ. Agric. Research*, II, 1914, p. 405.

carried this disease. Yet it is remarkable that though chestnut blight has been in the neighbourhood of New York since 1904, it had not, up to 1913, been able to cross a chestnut-tree belt in the Catskill mountains, some 30 to 40 miles broad, running roughly north and south, parallel to and just west of the heavily infected Hudson River Valley.* So far as the spread from east to west is concerned birds can, therefore, have played little part.

The diseases liable to be carried by birds would naturally be chiefly those affecting fruit and forest trees and producing spores on the upper parts of the tree.

Outside birds, the only other animals that might perhaps help to disseminate fungi over large distances are insects. In some cases these have a power of dispersal probably unequalled even amongst birds.† That they should carry spores would seem to be a most natural assumption. Possibly they have done so in many cases in the past, and there may now only be a residue of cryptogamic parasites in each land area which, for some unknown reason, is unsuited to dispersal by birds and insects. It is only within comparatively recent times that any record has been kept of the appearance of new fungal diseases in certain parts of the world, and it is quite possible that all or nearly all of these belong to this residue. Since, however, the object of the present paper is primarily a discussion of the means by which parasites hitherto confined to one locality are, at the present time, able to reach areas separated by the ocean or by large tracts with unsuitable host plants, and since there is no evidence that birds or insects are now a considerable agency in effecting this spread, what may have happened in the distant past is not of direct consequence.

A second means of discontinuous spread is through the air. Though it is somewhat difficult to understand why this should not suffice sooner or later to spread most diseases over those parts of the world with suitable climates, yet such evidence as is available points altogether in the opposite direction.

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* *Cornell University Agric. Exper. Stat. Bull.*, No. 347, 1914, p. 545.

† Tutt, J. W. "The Migration and Dispersal of Insects," London, 1902.

The bulk of the evidence is circumstantial. Direct experiments are few and do not seem to have been framed so as to ascertain how far spores might be carried by the wind in storms or when the spores of, say, oat smut are sent into the air in clouds during threshing. Concordant results have been obtained in Germany and Russia that "spore traps" remained free from smut spores beyond 250 yards from heavily infected fields, though at Pullman, in the United States, the spores may fall copiously at a distance of a quarter of a mile. The area around barberry bushes through which black rust of wheat (which spends part of its life on the barberry) can be disseminated to the wheat is also said to be remarkably low. There are, however, various records in the case of rusts in which there are two hosts, where one appears to have become infected from the other through moderate distances. *Coleosporium Euphrasiæ* seems to reach the islands off the north-west German coast from the mainland* and other cases are recorded of the occurrence of one stage of these fungi from 5 to 8 miles from the plant bearing the alternate stage. The general results of the investigations seem to show that the distance to which spores may be carried in the air has often been exaggerated in the past, and that it is much less than might be expected.† Even such small bodies fall gradually when in the air and it has been found‡ that the spores of some of the higher fungi fall at the

* This and several other interesting cases are quoted by Klebahn ("Wirtswechselnden Rostpilze" 1904.)

† I believe a somewhat similar conclusion has been reached by plant breeders with regard to the distance to which pollen grains may be carried by the wind; and the long controversy with regard to air-borne infection in such human parasitic diseases as scarlatina and cholera has ended in the same way. Indeed the whole of our modern sanitary regulations dealing with quarantine and the restriction or isolation of infectious diseases, are based on the view that it is the living carrier and objects, such as clothing, which have come into contact with infected persons, that constitute the danger. Even the long-lived and minute organism of scarlatina is not believed to be carried in the air to more than a very limited distance and did not reach many parts of the world until long after it had been known in Europe. As would be expected the evidence regarding the dissemination of the seeds of higher plants is to the same effect and even the small spores of ferns have not been of advantage to this group in enabling it to colonise distant areas more readily than the flowering plants (H. Christ, "Die Geographie der Farne," 1910).

‡ Buller, A. H. R. "Researches on Fungi," 1909, Chaps. XV and XVI.

average rate of 0·5—5 mm. per second in still air, and so must come to earth before very long.

On the other hand, it is well established that dust particles (which are of the same order of size as spores) can be carried to great distances under certain conditions. The dust from the volcanic eruption of Krakatao in 1883 travelled thousands of miles, that from Vesuvius and Etna has reached Constantinople, Norway has been strewn with volcanic dust from Iceland. In these cases the dust has been probably thrown up to a great height by the eruption and its lateral spread may be accounted for by this. But dust has also been carried a long way when blown from the ground by storms. From North Africa it is said to have reached a considerable part of southern Europe ; while the wind known as the Harmattan, which takes its rise in the Sahara, blows clouds of dust far out into the Atlantic in a south-westerly direction from the Senegambia and Guinea coast. This dust has often fallen on vessels several hundred, and even more than a thousand, miles out to sea, and Darwin collected particles of stone, over a thousandth of an inch square, 300 miles from land. These would exceed in size and weight the spores of many fungi. It would seem natural to suppose that spores might equally be carried for at least some hundreds of miles, were it not that there is a great deal of circumstantial evidence against this to support the direct evidence mentioned above.

This evidence is based on the known distribution of the minute plants which cause disease. It may be divided into two classes. The spread of a limited number of diseases has been closely observed and has not been found to be such as would be accounted for by long-distance spread through the air. The geographical distribution of some groups of parasitic fungi has also been worked out and seems equally to exclude this possibility in a certain number of cases."

* * * * *

" Of the large groups of fungi whose geographical distribution opposes the view that living spores can be borne for long distances in the air, the rusts afford some interesting examples. In the genus *Uromyces* there are 119 species in Europe, of which 70 are endemic

(recorded up to 1911.) Yet of these Europe has only transmitted three (*Uromyces Betæ*, *U. caryophyllinus* and *U. Trifolii*) to North America, while two (*Uromyces striatus* and *U. Fabæ*) are doubtful. In turn it has only received a single species (*Uromyces appendiculatus*) from North America, though the genus is very well represented there and no less than 249 species have been recorded in North and South America combined, of which 221 are endemic. It is worthy of note that all the exchanged species are parasitic on cultivated plants. Australia, which has 32 species, of which 22 are endemic, has only received six from outside and these six are the same as those which have traversed the Atlantic.* Another rust genus, *Phragmidium*, which is parasitic on plants of the N. O. *Rosaceæ*, is also of interest in its distribution. Over 60 species are known, but none are endemic in South America (though there is one in the Falkland Islands) and only one has been introduced, *Phragmidium disciflorum* on roses.† Though there are many species in southern and eastern Asia, only 4 (or perhaps only 2) are known in Australia and only one of these has been introduced, the same one as to South America, also on roses. These rusts are not, so far as is known, more exacting than many other parasitic fungi in their climatic or other requirements ; their spores are numerous and the least resistant type can often live for several weeks, while the durable spores, that are set free as the host plant withers (or sooner in *Phragmidium*), live for months ; and though they are strictly parasitic and confined to definite hosts, this would not be sufficient to account for so markedly restricted a distribution if they were capable of wind dissemination for long distances.

From this consideration of the evidence available the conclusion to be drawn is that in devising methods to prevent the introduction of new diseases of the type of those contained in the detailed list attached (which includes a considerable proportion of the destructive diseases introduced within the 70 or 80 years during

* The above details are mostly on the authority of P. Dietel (*Ann. Mycol.*, IX, 1911, p. 160) who has given special attention to the geographical distribution of rusts. McAlpine (1906) gave a seventh species (*Uromyces Polygoni*) as having been introduced into Australia.

† Dietel, P., in *Ann. Mycol.*, XII, 1914, p. 93.

which we have reliable records, and represents practically all the classes of parasites likely to spread extensively in the future) infection by spores carried through the air from remote centres is not a contingency which needs to be taken seriously into account."

(*To be continued.*)

NOTES.

Thrips.—A curious form of *Thrips* attack has recently occurred on a garden in Upper Assam, which it is desirable to describe, as it may possibly turn up elsewhere.

The insect lives and feeds within the channel inside the partly opened bud, rasping away part of the leaf tissue from what will eventually be the under surface of the leaf. When the bud opens the damage can be seen on the newly-formed leaf as two pale lines running along the leaf almost parallel to and some distance from the midrib. A close scrutiny of these lines shows that on the upper surface of the leaf the surface is convex, while on the under surface it is concave and somewhat roughened. As the leaf gets older the convex lines on the upper surface become more marked, and the damage under surface assumes a more pronounced corky appearance. The final result, as seen on the old leaves, is that two strongly pronounced raised lines, parallel, and generally almost equidistant from the midrib, are to be seen on the upper surface, while two corresponding strongly pronounced corky lines are to be seen on the lower surface, the corky growth being in some cases so pronounced that the lines are raised, in other cases less so, so that they still appear to be concave. In some cases this attack is accompanied by slight distortion of the leaves.

The area most affected was a young clearance of Burma plants, put out seed at stake last cold weather on thatch land. In this area almost every plant was affected. An adjoining area, put out the year before, was also affected, and traces of attack were to be found in four-year old tea still further away. In all cases no further damage than that above described seemed to have occurred.

Two points were noticed which seemed to confirm the observation that the insect confines its attacks to the unopened and opening buds. No trace of the insect could be found on any open leaf. In the young tea, which had never been plucked, in the

majority of instances every leaf younger than that first attacked showed signs of the pest, while in the older tea which had been regularly plucked the characteristic marks could as a rule only be found on comparatively old leaves the insects having apparently been removed with the buds by the pluckers.

The remedy for this pest therefore appears to lie in plucking the buds from young tea which is affected, while no harm need be feared in plucking tea as the ordinary routine of plucking removes the insects.

Insect pests of tea in Ceylon during 1916.—The following information is taken from Ceylon Administration Reports, 1916, part IV—Department of Agriculture, Report on the work of the Entomological Division, pp. C7 to C8.

Tea Tortrix (*Homona coffearia*) has been very severe throughout the year in Maskeliya, Central Province; out-breaks have also been reported in January at Dehiowita, Province of Sabaragamuwa; in June at Demodara, Uva; in November at Ratnapura, Province of Sabaragamuwa; and Talawakele, Central Province.

The small Tussock Moth (*Orgyia postica*) has been reported in the caterpillar stage in January at Talawakele, Central Province; in October at Kandy, Central Province.

The Fringed Nettle Grub in May and July at Dehiowita, Province of Sabaragamuwa.

The Red Borer (*Zeuzera coffeae*), in January at Pelmadulla, Province of Sabaragamuwa; in May at Bentota, Southern Province; in June at Balangoda, Province of Sabaragamuwa; in July at Haputale, Province of Uva; in August at Ingiriya, Western Province; in October at Kuruwita, Province of Sabaragamuwa; in November at Badulla and Bandarawela, Province of Uva. In the Badulla District of the Province of Uva the caterpillars have been heavily parasitized by Braconids, which were hatched from their cocoons in November.

Bagworms (*Psychidae*) have been reported in October from Ingiriya.

Shot-hole Borer (*Xyleborus fornicatus*) has shown the usual tendency to increase its distribution ; but, with the exception of Upper Hewaheta, Central Province, no actually new districts have been invaded. In the Kandy District there has been a marked decrease on certain estates, due to climatic conditions. In Uva, on the other hand, it has increased locally. It is under special investigation. A number of estates have been added to the register, but it has been found necessary to remove others after further investigation. In future it has been decided that no estates will be registered before specimens of infected bushes have been examined by the Entomological Division, and estates submitting reports of infestation are asked to send in specimens at the time of report.

Xyleboridae.—Two specimens, distinct from *X. fornicatus*, have been recorded in tea in the Balangoda (Province of Sabaragamuwa) and Badulla Districts (Province of Uva), theformer affecting dead twigs only. Both are very minute, being markedly smaller than true shot-hole borer. Another small species, probably *Xyleborus coffeae*, was collected in nurseries at Kamburupitiya, Matara (Southern Province).

Tea Weevil (*Astycus sp.*) was reported from Uda Pussellawa, Central Province, in March.

The Barking-eating Borer (*Arbela quadrinotata*) was reported in January from Kotagala, Central Province.

Ricanoptera opaca—an apparently new pest of tea—made its appearance in Madulsima (Province of Uva) in May. The outbreak of this plant-bug apparently only lasted a short time.

Lecanium viride was reported from tea at Bandarawela (Province of Uva) in August. Examined in September ; a few bushes in a small acreage (30 acres) were found to be attacked.

During the unusually long drought which prevailed over most of the tea districts in the early part of the year, the tea mites were much in evidence, though but few reports were received. The coming of the rains put a stop to their activities.

The Purple Mite (*Phytoptus carinatus*) was apparently the commonest, but also disappeared with the rains.

Psocidae.—A curious case of infestation of made tea by these insects, which are allied to "termites" or "white ants," was received from a Colombo firm in November. The matter is still under investigation, but it seems probable that the insects were originally present on the wood of the tea chests and obtained admittance to the tea before packing or through perforated tea lead.*

Shot-hole Borer.—The following summary of the results of recent investigations on Shot-Hole Borer is taken from Ceylon Administration Reports, 1916, part IV, Department of Agriculture, Report on the work of the Entomological Division, p. C9.

THE TREATMENT OF PRUNINGS.—A systematic examination was made of tea prunings buried with basic slag and sulphate of potash on the Keenagahaella estate, Balangoda. It was found that up to two months after burying prunings to a depth of 1 foot 6 inches the insect was still breeding underground, and negative evidence was forthcoming that the beetles were finding their way to the ground surface. Upon this and previous investigation the system of burying prunings on estates has been deprecated, and the burning of the woody parts of prunings has been advocated. On the Poonagalla group it was found both economic and advantageous to fork in the leaves after cutting them from the prunings and burn only the woody parts. Observations were made upon the effect of breaking the branches attacked by the borer and leaving these attached to the bushes. After fourteen days living insects were found in these branches below the point of rupture. The exposure of portions of the galleries of the beetle, therefore, does not hinder the development of the insect in other parts not exposed.

PAINTING TEA BUSHES.—The results of an experiment made in October, 1915, with resin mixture were obtained. Twelve washes made up of varying proportions of resin, soda, creosote, fish oil, and carbolic acid had been applied to plots of fifteen newly-pruned tea bushes. Four of these were found to be too thin in

* A species of this family has been found to attack stored tea in Assam (See Indian Tea Association, Scientific Department, Quarterly Journal, Part III, 1914, p. 114.) In this case the tea had been stored, not in wood boxes, but in air-tight sample tins.

composition to protect the wood from the borer. The others were satisfactory in as far as they formed a varnish, which would definitely prevent entry or emergence of the insects. Six of the remainder washed off too easily with the monsoon rains. This left two, which were temporarily satisfactory. Examined in January, 1916, four months later, the bushes thus treated were making no growth, so that the experiment was not proceeded with. However, in January, 1917, these bushes were found to have recovered completely, and further experiments are being made with the preparation of washes, which may act as protections to the young buds.

CASTOR-OIL TREE (*Ricinus communis.*)—An experiment was arranged under canvas to determine if the castor-oil tree could be used effectively as a trap for shot-hole borer. Tea bushes were transplanted and placed with unaffected castor-oil trees in October, 1915. In January, 1916, the castor-oil trees were heavily attacked, but the infestation had not been reduced in the tea bushes. It is, therefore, concluded that the castor-oil trees will not be satisfactory as a trap for the borer.

SHOT-HOLE BORER IN GREVILLEA AND DADAP.—Experiments were carried out on the Poonagalla group to determine what species of *Scolytid* beetle attacked the surfaces of grevillea trunks after removal of the bark. After eighteen days 31 beetles were extracted from the cut surfaces, 23 specimens of *Xyleborus semigranosus* (?), 7 specimens of *Xyleborus semiopacus*, and only one specimen of *Xyleborus fornicatus*, true shot-hole borer. The latter insect, however, was found to attack dadaps at the point of "ringing" in profusion, and the burning of the ringed surfaces four to forty days after this practice has been recommended.

The Quarterly Journal.—Several suggestions for minor improvements of this journal have reached us recently. These improvements will be given effect to in the first issue for 1918 and afterwards. Suggestions are always welcome.

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